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Introduction

Liquid aerosols are efficient vectors for drug delivery in upper and lower respiratory tract. Characteristics of inhaled particles, flow properties, and airway morphology represent the main influential factors of the transport mechanisms. Numerous works have been carried out to characterize the airflow behaviour during human breathing [Baier, 1977; Brancatisano, 1983], and to determine the trajectories of inhaled particles through the extrathoracic region. Recent studies [Brouns, 2007] have shown the relevance of the laryngeal geometry and, more precisely, the impact of glottal aperture on fluid dynamics and aerosol deposition mechanics. In this study we focus on two main objectives: i) determine the glottal dynamics during two breathing conditions (*eupnea* and *tachypnea*); ii) predict the influence of both carrier gas and aerosols' properties on the unsteady laryngeal flow and the aerosol deposition, using CFD simulations in a simplified 3D glottis model during these two breathing conditions.

Methods

A clinical study was conducted at the ENT department of La Timone hospital at Marseille, France. The study consists in recording simultaneously the oral airflow rate during breathing, using EVA2 sensor [Ghio, 2004], and the glottis motion, using a flexible nasofiberscope (Storz 202220).

According to these results, a 3D model of the glottis motion was designed and used to simulate the 3D unsteady laminar flow during inspiration and expiration within the ANSYS CFD code. The unstructured hybrid mesh consists of 1 301 281 tetrahedral and hexagonal elements, refined near the walls. The fluid is assumed to be incompressible and Newtonian.

Results

Recorded measurements allowed us to compute the mean temporal evolution of the glottal aperture during breathing. Figure 1 shows the evolution of the normalized flow rate and glottis area during a complete breathing cycle for *eupnea* and *tachypnea*. The commonly used sinusoidal pattern is also shown for comparison.

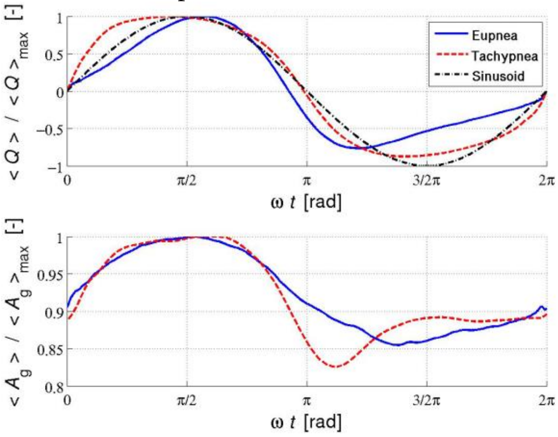

Figure 1: Normalized mean flow rate and glottis area evolution during breathing cycle.

In the case of *tachypnea*, recorded flow rate patterns show stronger unsteady effects, enhanced by the constriction of the glottis.

The CFD results exhibit also a strong laryngeal jet behind the glottis at the maximal flow rate. Using a Lagrangian approach, the pathlines of spherical droplets, injected at the inlet surface of the model, are computed for Stokes number in the range of 1.5 10^{-3} - 2.0 10^{-2}. A large number of these droplets are trapped by the glottal wall and further downstream by the tracheal wall where the flapping jet impacts. The influence of different carrier gases, including helium-oxygen mixture, on the aerosol deposition and respiratory biomechanics will be presented.

Discussion

Our results show that considering the oral flow rate as a pure harmonic signal is not realistic. Indeed important unsteady effects, connected with the real breathing conditions, are not taken into account. These effects are strongly strengthened by the glottis motion especially during the changing from inspiration to expiration.

References

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